RESEARCH BULLETIN 1158 MAY 1984

Invasion of Volunteer Tree Species on Stripmine Plantations in East-Central Ohio

M. M. LARSON

The Ohio State University
Ohio Agricultural Research and Development Center
Wooster, Ohio

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ACKNOWLEDGMENTS

The research reported here was supported in part by funds provided by the U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. Personnel, physical facilities, and funding for publication of this report were provided by the Ohio Agricultural Research and Development Center, Wooster. The research was cooperatively carried out in accordance with the work plan, Evaluation of 1946-47 Plantations on Strip-Mine Spoils in Southeastern Ohio, Agreement No. 23-739, dated May 12, 1975, Northeastern Forest Experiment Station and Ohio Agricultural Research and Development Center.

Cooperation of the Ohio Mining and Reclamation Association and its individual corporate members who permitted access to their lands is acknowledged. Employees and former employees of the Association, including Donald Richter, William Dietrich, and William Augur, were instrumental in locating experimental plantings.

The technical assistance of Charlton Aten in planning the field work and collection of data is greatly appreciated.

ON THE COVER: Inventory of volunteer trees in a planted white ash subplot on Plantation 8 near Alliance, Ohio. Technician Charlton Aten records the volunteer species on one of the sample quadrats marked by a string boundary.

AGDEX 300/23-44

5-84-2M

Invasion of Volunteer Tree Species on Stripmine Plantations in East-Central Ohio

M. M. LARSON[1]

ABSTRACT

The species and density (number and basal area per acre) of volunteer trees in 30-year-old stands of white pine, black locust, white ash, and yellow-poplar were determined on three stripmine areas, each of a different spoil type.

The number of volunteer trees varied with spoil type, with 929 trees per acre on near-neutral spoils derived from glacial till and sandstone, 698 trees per acre on acidic (pH 3.8-5.5) shaly sand spoil, and 516 trees per acre on calcareous limestone and clay spoil. Black cherry seedlings were the predominant volunteers on neutral and acidic spoils, while black locust and white ash predominated on the calcareous clay spoil. Presence of a particular volunteer species was also related to presence of a nearby seed supply.

Volunteer trees outnumbered planted trees at a 7:4 ratio, all areas combined, but planted trees accounted for 73% of the total basal area.

The number (but not basal area) of volunteer trees significantly differed between stands of the four planted species in each spoil type. Planted black locust stands were preferentially invaded by volunteer trees, especially black cherry. Planted white pine stands had the fewest volunteers except on calcareous clay spoil.

The importance of the volunteer component in these stands is expected to increase, although species composition of future stands is unclear.

INTRODUCTION

Many tree species invade planted stands on stripmined areas. After a time, invader or volunteer trees often become an important component of the final stand and in some cases outnumber planted trees (4, 8).

Thus, the importance of volunteer components justifies a closer look at the ecological relationships between planted and volunteer trees. The main purpose of this investigation was to determine number and basal area of volunteer trees by species in 30-year-old stripmine plantations. Two questions of particular interest were: are some spoil types more favorable than others for invasion by volunteer trees, and do plantations of various species differ as to kind and amount of volunteers that develop on them?

PROCEDURES

In 1946-47, the Central States Forest Experiment Station, Ohio Reclamation Association, Ohio Division of Forestry, and several private coal companies cooperated in the establishment of planting and seeding studies located on a variety of stripmined areas in eastern and southeastern Ohio. Thirteen of these plantations were relocated and measured in 1975 and early 1976. Of these, three plantations were considered suitable in size and design for study of volunteer trees. The location and soil description of each plantation are shown in Figure 1 and Table 1. The greatest distance between any two of the three plantations is less than 50 miles.

Each plantation consisted of several subplots, each planted to a single species. Subplots were 70 ft square (0.11 acre) on Plantation 8 and 105 ft square (0.25 acre) on Plantations 3 and 7.

Only subplots originally planted to either white pine, yellow-poplar, white ash, or black locust and which had 160 or more surviving trees per acre in 1975-76 were selected for study. The 160-tree lower limit insured that moderate amounts of planted trees were present on the subplots selected for study of volunteer species. The numbers of planted subplots studied at each plantation are given in Table 2. Common and scientific names of all trees mentioned in the report are given in Appendix Table III.

The number and diameter of all volunteer and planted trees by species were measured on a 41.7 ft square (0.04 acre) sample plot located in the center of each plantation subplot. Distance from sample plot boundary to the surrounding subplot boundary was either 14.1 ft or 31.6 ft, depending on subplot size. In the field, the square-shaped sample plots were further divided into four equal quadrats to facilitate inventory of trees. Natural reproduction of planted species was included in the volunteer inventory, except for black locust reproduction found inside subplots planted with black locust (see Results, page 3, for more discussion of this subject).

On Plantation 3, 4 of the 14 subplots were located on spoils that had been leveled before planting in 1946. The four leveled subplots included one white ash subplot, one black locust subplot, and two white pine subplots. Data for volunteer trees on leveled and unleveled plots appeared to be similar, and were combined in statistical analyses.

Point samples with a BAF-10 prism were taken at the center of each of the four quadrats in the sample plots described above. Point sampling data were summarized but not statistically analyzed because the method inadequately measured density and number of species of volunteer trees. The weaknesses of the point sampling method in studies of the present type are discussed by Sipp and Bell (14).

STATISTICAL ANALYSIS

The relationship between plantation location and planted tree species to number and basal area of volunteer species on sample plots was analyzed by the method

[1]Professor, Division of Forestry.

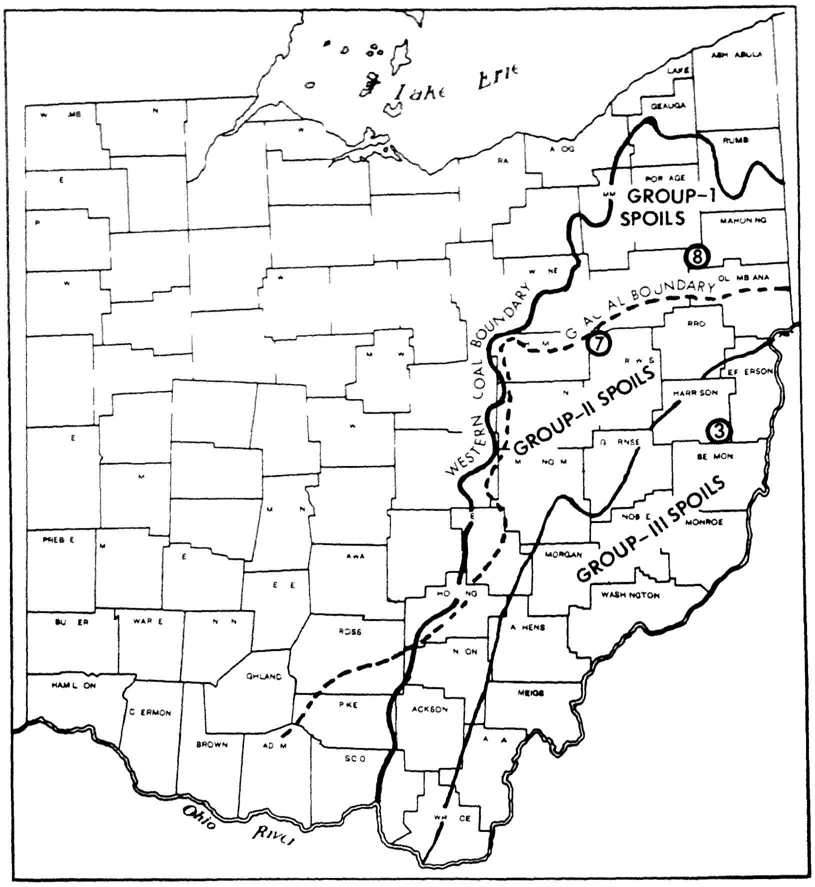

FIG 1 —Location map of Plantations 3, 7, and 8 in east-central Ohio Also shown are boundaries of three major spoil types described in 1944 (7) as follows Group I spoils glacial till, residual sandstone, seams 4, 5, 6, Group II spoils unglaciated sandstone, acid silt shale, seams 5, 6, Group III spoils unglaciated sandstone coarse limestone, marly clays, seam 8

TABLE 1.—Soil Description of Three 30-Year-Old Stripmine Plantations Selected for Study of Volunteer Tree Species.

Plantation	Nearest Town	Stripmine Soil pH	Stripmine Soil Description
3	Georgetown	>7 0 (calcareous)	Coarse limestone and clay
7	Dundee	3 8 to 5 5 (acid)	Shaly sand and stony sand
8	Alliance	6 5 to 7 8 (near neutral)	Glacial till silty shale loam to sandy loam

of least-squares for unequal subclasses (10). This type of analysis also permitted calculation of residual correlations between dependent variables after treatment effects were removed.

Since the density of planted trees varied from sample plot to sample plot, both number and basal area of planted trees were included as covariates in a second statistical analysis of volunteer tree data. This procedure, in effect, allows one to evaluate plantation location and planted species effects without bias due to differences in density of planted trees on sample plots.

However, comparison of the first analysis without covariates to the second analysis with covariates revealed few important differences, as indicated by similar probability levels of the F-tests (Appendix Table I). Unless stated otherwise, the following results are based on the analysis without covariates.

RESULTS

The number of volunteer trees per acre varied with plantation location (Table 3). Plantation 8 located on near-neutral spoils had higher numbers of volunteer trees than either Plantation 7 on acid spoils or Plantation 3 on calcareous spoils. In general, Plantation 3 was characterized by good survival but poor growth of planted trees, and by relatively low numbers and poor diameter growth of volunteer trees (Tables 3, 4, and 5).

Twenty volunteer tree species were found on the three plantations (Table 3, Appendix Table II). Black cherry was the most abundant volunteer on two plantations, with greatest numbers (407 trees per acre) on Plantation 8. As a rule, however, each volunteer species was relatively abundant on only one of the three plantations; *e.g.*, black cherry and hawthorn on Plantation 8, white ash on Plantation 3, and red maple on Plantation 7 (Tables 3 and 4).

The number of volunteer trees for each planted species type at each of the three plantations ranged from 257 to 1192 trees per acre (Table 5). On Plantations 7 and 8, mean number of volunteer trees was higher in black locust stands (1083 trees per acre) than in white pine stands (462 trees per acre). In contrast, white pine stands had the highest mean number of volunteers (855 trees per acre) at Plantation 3.

Volunteer trees outnumbered planted trees on each of the three plantations, with an overall mean for the plantations of 714 volunteer trees to 401 planted trees per acre. However, planted trees had a total mean basal area of 55.7 ft^2 compared to only 20.3 ft^2 per acre for volunteers.

Planted black locust stands probably contain more black locust volunteers than indicated because of the inability to include natural reproduction as part of the volunteer inventory. When the 30-year-old black locust stands were inventoried, all living black locust trees were classed as planted because of the near-impossibility of identifying which trees were planted and which were of sprout or seed origin (Fig. 2). Black locust can reproduce by root suckers and produces seed at about age 6 (9). However, black locust trees found on

TABLE 2.—Number of Planted Subplots by Species in Each of Three Stripmine Plantations Selected for Study of Volunteer Tree Species.

Species Planted on Subplots	Plantation 3	Plantation 7	Plantation 8
		no.	
White pine	5	9	6
Yellow-poplar	3	5	2
White ash	4	3	3
Black locust	2	3	3

TABLE 3.—Mean Number of Each of the Eight Most Abundant Volunteer Tree Species* and Total Number of Volunteer Species Found on Plantations 3, 7, and 8.

Volunteer Tree Species†	Plantation 3 (calcareous)	7 (acid)	8 (near-neutral)
		no. per acre	
Black cherry	89 b	177 b	407 a
Black locust	181 a	144 a	91 a
White ash	176 a	74 ab	17 b
Hawthorn	5 b	2 b	253 a
Red maple	0 b	170 a	7 b
Elm species	40 a	68 a	46 a
Dogwood	0 b	3 b	66 a
Sugar maple	19 ab	27 a	0 b
Other‡	6	33	42
Total volunteers	516 b	698 b	929 a
Volunteer species, no.	7	15	13

*Within each species, means not followed by a common letter are significantly different at 5% level, Duncan's new multiple range test.

†Scientific names of species given in Appendix Table III.

‡For list of these species, see Appendix Table II.

TABLE 4.—Mean Basal Area of Eight Volunteer Tree Species* and Total Basal Area of Volunteers on Plantations 3, 7, and 8.

Volunteer Tree Species	Plantation 3 (calcareous)	7 (acid)	8 (near-neutral)
		square feet per acre	
Black cherry	1.26 b	11.50 a	12.02 a
Black locust	7.80 a	8.02 a	8.32 a
White ash	0.26 b	1.92 a	0.22 b
Hawthorn	0.04 b	0.01 b	2.74 a
Red maple	0 b	2.74 a	0.01 b
Elm species	0.48 a	0.48 a	1.00 a
Dogwood	0 b	0.04 b	0.13 a
Sugar maple	0.52 a	0.70 a	0 a
Other†	2.87	1.09	1.83
Total Volunteers	13.23	26.50	26.27

*Within each species, means not followed by a common letter are significantly different at 5% level, Duncan's new multiple range test.

†See Appendix Table II.

TABLE 5.—Mean Number, Diameter, and Basal Area of Both Volunteer and Planted Trees in Each Planted Stand Type in Plantations 3, 7, and 8.

Plantation and Planted Stand Type	Volunteer Trees*†			Planted Trees†		
	Number	Diameter	Basal Area	Density	Diameter	Basal Area
	no./acre	inches/tree	ft^2/acre	no./acre	inches/tree	ft^2/acre
Plantation 3 (calcareous)						
White pine	855 abc	1.8 bc	20.0 ab	345 bcd	4.6 cde	52.8 bcd
Yellow-poplar	257 d	2.0 bc	16.0 ab	450 abcd	5.0 bcde	67.5 abc
White ash	412 cd	1.6 cd	7.8 b	625 a	3.5 def	48.0 bcd
Black locust	538 bcd	1.2 d	8.5 ab	538 ab	2.0 f	19.3 d
Plantation 7 (acid)						
White pine	375 cd	3.1 a	28.0 ab	260 d	6.8 ab	86.0 ab
Yellow-poplar	680 abcd	1.8 bc	20.5 ab	320 cd	5.6 abc	62.5 bcd
White ash	768 abcd	1.7 cd	17.8 ab	357 bcd	3.3 ef	24.3 cd
Black locust	975 ab	2.2 b	39.0 a	268 d	4.7 cde	31.5 cd
Plantation 8 (near-neutral)						
White pine	550 bcd	1.7 bc	23.5 ab	383 bcd	5.5 abc	85.0 ab
Yellow-poplar	900 abc	1.3 d	23.7 ab	412 bcd	3.1 ef	48.3 bcd
White ash	1074 a	1.2 d	38.2 ab	500 abc	3.1 ef	37.5 cd
Black locust	1192 a	1.2 d	19.0 ab	357 bcd	7.1 a	105.3 a

*All species combined.

†Significant differences at 5% level among means within each column indicated when means are not followed by a common letter, Duncan's new multiple range test.

subplots planted to other species were classed as volunteers (Tables 6 and 7).

Natural reproduction of white ash on white ash subplots was more easily recognized and these trees were classed as volunteers. Little confusion occurred here because natural reproduction was a distinctly smaller class. For example, all white ash trees found on white ash subplots in Plantation 3 were judged to have been planted (Table 4), with 96% of the trees 2 inches or larger in diameter. In contrast, subplots planted with other species had large numbers of white ash volunteers of which 97% were 1 inch or less in diameter. On Planta-

FIG. 2.—Black locust stand 30 years after planting. The stand contains locust trees of planted, sprout, and seed origin which are difficult to identify from each other.

TABLE 6.—Number of Trees of the Eight Most Abundant Volunteer Species* in Four Planted Stand Types in Plantations 3, 7, and 8.

Plantation and Planted Stand Type	Black Cherry	Black Locust	White Ash	Hawthorn Species	Red Maple	Elm Species	Flowering Dogwood	Sugar Maple
	Volunteer Species							
	no per acre							
Plantation 3 (calcareous)								
White pine	65 d	245 ab	465 a	20 c	0 b	60 ab	0 b	0 b
Yellow poplar	117 d	75 b	50 b	0 c	0 b	0 b	0 b	0 b
White ash	0 d	406 a	0 b	0 c	0 b	0 b	0 b	0 b
Black locust	175 bcd	†	187 b	0 c	0 b	100 ab	0 b	75 a
Plantation 7 (acid)								
White pine	61 d	125 ab	70 b	0 c	72 b	28 b	0 b	14 b
Yellow poplar	105 d	85 b	75 b	0 c	285 a	85 ab	5 b	5 b
White ash	125 d	367 a	17 b	8 c	83 b	8 b	8 b	83 a
Black locust	417 bc	†	133 b	0 c	242 a	150 a	0 b	8 b
Plantation 8 (near neutral)								
White pine	150 cd	29 b	25 b	412 bc	4 b	33 b	62 a	0 b
Yellow poplar	187 bcd	187 ab	25 b	772 ab	25 b	75 ab	75 a	0 b
White ash	383 bc	150 ab	17 b	947 a	0 b	42 b	67 a	0 b
Black locust	908 a	†	0	370 bc	0 b	33 b	58 a	0 b

*Significant differences at 5% level among means within each column indicated when means are not followed by a common letter Duncan s new multiple range test

†Planted and volunteer black locust trees not differentiated (see text)

tions 7 and 8, white ash reproduction on white ash subplots averaged only 18 trees per acre (Table 6), although many of the planted trees were of seed-bearing size and were currently producing seed

More black cherry volunteers were found in planted black locust stands than in stands of other species (Tables 6 and 7) Mean basal area of black locust volunteers in planted locust stands was 4 3 times greater for Plantation 7 than for Plantation 8 although Plantation 8 had the greatest number of black cherry trees

Another favorable association is indicated by the high number of volunteer black locust trees (150 to 406 trees per acre) found in white ash stands (Table 6) However, differences in mean basal areas of volunteer

TABLE 7.—Basal Area of the Eight Most Abundant Volunteer Species* in Planted Stand Types in Plantations 3, 7, and 8.

Plantation and Planted Stand Type	Black Cherry	Black Locust	White Ash	Hawthorn Species	Red Maple	Elm Species	Flowering Dogwood	Sugar Maple
	Volunteer Species							
	square feet per acre							
Plantation 3								
White pine	0 26 c	17 73 a	0 74 a	0 07 b	0 a	0 45 a	0 a	0 a
Yellow poplar	0 26 c	7 93 a	0 22 a	0 b	0 a	0 a	0 a	0 a
White ash	0 c	5 53 a	0 a	0 b	0 a	0 a	0 a	0 a
Black locust	4 49 bc	†	0 22 a	0 b	0 a	1 88 a	0 a	2 13 a
Plantation 7								
White pine	5 00 bc	17 16 a	2 18 a	0 b	1 75 a	0 30 a	0 a	0 88 a
Yellow poplar	5 49 bc	6 53 a	2 79 a	0 b	5 00 a	0 22 a	0 02 a	0 02 a
White ash	5 23 bc	8 36 a	0 09 a	0 50 b	1 26 a	0 05 a	0 05 a	1 82 a
Black locust	30 49 a	†	2 61 a	0 b	3 00 a	0 92 a	0 a	0 05 a
Plantation 8								
White pine	10 50 bc	4 40 a	0 78 a	1 48 b	0 04 a	2 90 a	0 15 a	0 a
Yellow poplar	15 25 b	6 01 a	0 13 a	0 50 b	0 02 a	0 68 a	0 08 a	0 a
White ash	6 75 bc	22 91 a	0 02 a	8 01 a	0 a	0 20 a	0 22 a	0 a
Black locust	15 51 b	†	0 a	0 87 b	0 a	0 50 a	0 05 a	0 a

*Significant differences at 5% level among means within each column indicated when means are not followed by a common letter Duncan s new multiple range test

†Planted and volunteer black locust trees not differentiated (see text)

black locust in any of the planted stands were not significant, although there were large variations among these data (Table 7).

Planted stands varied in density (number and basal area) according to species (Table 5). White ash stands had relatively high numbers of trees as compared to white pine and yellow-poplar stands. An outstanding plantation effect was that planted black locust grew exceptionally well on Plantation 8, averaging 105.3 ft^2 per acre basal area, compared to less than 32 ft^2 on the other two plantations.

Volunteer trees on subplots varied with plantation location and with species of trees planted. In general, these relationships were significant even after effects of amount of planted trees present were statistically removed (see Statistical Analysis, page 1, and Appendix Table I). This is not to say that amount of planted trees present did not influence volunteers. There were low, but significant, residual correlations between density of volunteer species and density of planted trees on subplots. Correlation coefficients in Table 8 suggest that volunteer trees in subplots decreased as planted trees increased. The largest negative correlation (r = —0.643**) was between number of planted trees and total basal area of volunteers (species combined). Black locust volunteers were negatively correlated with number and basal area of planted trees, but these data may be somewhat biased by the fact that black locust volunteers could not be recognized on black locust subplots. White ash, dogwood, and sugar maple were not significantly correlated with either number or basal area of planted trees (Table 8).

TABLE 8.—Residual Correlation Coefficients*, † for Number (no.) and Basal Area (ba) of Eight Volunteer Species Correlated with Number and Basal Area of Planted Trees (Species Combined) on Subplots.

Volunteer Species	Correlation with Planted Trees, no. (r)	Correlation with Planted Trees, ba (r)
Black cherry, no.	—0.380 *	—0.203 ns
Black cherry, ba	—0.468 **	—0.391 *
Black locust, no.	—0.424 **	—0.451 **
Black locust, ba	—0.608 **	—0.484 **
White ash, no.	—0.092 ns	—0.034 ns
White ash, ba	—0.120 ns	—0.024 ns
Hawthorn, no.	0.342 *	0.289 ns
Hawthorn, ba	0.279 ns	0.173 ns
Red maple, no.	—0.254 ns	—0.323 *
Red maple, ba	—0.206 ns	—0.367 *
Elm, no.	—0.310 ns	—0.385 *
Elm, ba	—0.051 ns	0.103 ns
Dogwood, no.	0.039 ns	—0.177 ns
Dogwood, ba	0.236 ns	0.015 ns
Sugar maple, no.	0.254 ns	0.073 ns
Sugar maple, ba	0.234 ns	0.163 ns
Total volunteers, no.	—0.275 ns	—0.391 *
Total volunteers, ba	—0.643 **	—0.482 **

*Significance of r-values indicated as follows: ** = 1 % level, * = 5 % level, ns = not significant.

†"Within treatment" correlations that excluded effects of location and species of planted trees.

Subplots which contained a large number of volunteer trees did not necessarily show a proportionately large total basal area for volunteers. The coefficient of determination (r^2) between total number and total basal area of volunteers was only 0.132 (13.2% of the variation accounted for). Thus, both number and basal area measurements are important in the assessment of volunteer species in planted stands.

DISCUSSION AND CONCLUSIONS

The answer to the first question posed at the beginning of this report is yes, some spoil types appear to be more favorable than others for volunteer trees. This conclusion is supported by data reported here, if one assumes that sufficient volunteer seed fell on all three plantations and that other site differences were of minor importance. Thus, calcareous spoils of Plantation 3 seemed to be relatively unfavorable for establishment of volunteers, although the planted species survived well. Moderately acidic spoils of Plantation 7 had medium number of volunteer trees and their growth rate was good. Near-neutral spoils of Plantation 8 had the greatest number of volunteer trees at 929 trees per acre. In all three plantations, however, total number of volunteer trees exceeded the number of surviving planted trees.

In a study of problem spoilbanks in Illinois, Lindsay and Nawrot (12) noted that density of natural vegetation varied according to chemical characteristics of the spoil material, rather than time since mining.

The uneven distribution of volunteer species between the plantations studied here appeared to be related to differences in species composition of nearby stands. The numerous hawthorn and dogwood trees in stands adjacent to Plantation 8, and red maple trees adjacent to Plantation 7, were the probable seed sources for the volunteer trees of these species on these plantations. Seed of volunteer species is commonly carried by wind and birds to new areas. The few red oak volunteers on Plantations 7 and 8 probably originated from seed buried by squirrels. Also, some variation among volunteer species may be due to small microclimatic differences between plantations. However, the macroclimate of all three plantations is considered favorable for establishment and growth of all volunteer species found in this study.

The answer to the second question posed at the beginning of the report is also yes, species planted on stripmines influence volunteer trees, although the data indicate that relationships varied between plantations. Thus, black locust stands on Plantations 7 and 8 were favorable for establishment of volunteers, with a mean of 1084 volunteer trees per acre compared to a mean of only 445 volunteers per acre in planted white pine stands on these two plantations. However, white pine stands on the calcareous spoil of Plantation 3 averaged 855 volunteers per acre. Here, volunteer establishment, In an extensive study in Illinois, Ashby *et al.* (3) reported the number of volunteer tree species in each of five mining districts ranged from 13 to 28, and that each district had a different "most frequently found volunteer species." These species were elm, black cherry, cottonwood, oak, and dogwood. Ashby *et al.* (3) also reported that invasion occurred in two stages: first, early invasion by cottonwood and sycamore when areas were open; and second, later invasion by other species after planted trees or early volunteers were established.

In another Illinois study, Haynes and Klimstra (11) reported shingle oak, elms, black cherry, willow, boxelder, sycamore, and cottonwood as common invaders on spoils previously planted with either pines, black locust, or herbaceous pasture species. Vogel (17) listed the four most abundant volunteer species in 30-year-old plantations in Missouri, Kansas, and Oklahoma as black locust, elm, dogwood, and black cherry. Mean diameter of the four preceding species was more than twice that for the same four species in the study reported especially of white ash, may have been aided by the mitigating effect of pine on the high pH spoil conditions and/or the clay soil.

Among individual volunteer species, black cherry densities were highest in black locust stands, and white ash stands appeared to be quite favorable for black locust volunteers. The near-absence of white ash volunteers in white ash planted stands suggests an allelopathic relationship. Ashby *et al.* (4) reported that black locust stands in Indiana, Missouri, and Kansas were favorable for invasion by certain volunteer species but that dense stands of pine and maple discouraged invasion.

Several researchers have listed the most common volunteer tree species found on unplanted stripmined soils in their areas. In Ohio, a bottomland site 2 years after mining had volunteer trees of sycamore, sugar maple, elm, yellow-poplar, and white oak (13). In southeastern Indiana, 17 study areas had a total of 32 volunteer species (6). Of these, the four most abundant species were cottonwood, sassafras, persimmon, and black cherry. Also in Indiana, Stiver (15) listed red oak, elms, green ash, red maple, sycamore, cottonwood, sassafras, black cherry, black willow, and redcedar as the common volunteer species on slightly acid or calcareous stripmine soils. In western Pennsylvania, invader species were aspen, fire cherry, black cherry, and red maple (5).

here.

It is apparent from the above reports and from Table 3 of this report that there are many potential invader species. However, their occurrence on a particular site is determined by the presence of a nearby seed source, by spoil type, and by the amount and kind of vegetation already established on the area.

The early stages of forest succession on the three plantations are evident. Black cherry is the most abundant volunteer species on Plantations 7 and 8, and an important component of the volunteers on Plantation 3. In the future, black cherry and the somewhat more tolerant volunteers such as maple, ash, and elm will probably proportionately increase on most areas, especially as black locust trees are overtopped. The white pine stands appear to be in no danger of being overtopped by volunteers, except perhaps on a single subplot in Plantation 3. In every planted type, individual volunteer trees on favorable micro-sites outgrew nearby planted trees. Most volunteers, however, were understory trees.

The expected increase in importance of the volunteer component in these planted stands is indicated by a study of still older plantations in Pennsylvania. Davidson (8) evaluated 19 coniferous plantations ranging from 46 to 61 years of age on mined areas. Volunteer species accounted for one-third of the total volume on plantations. Black cherry was found in all plantings and outnumbered other volunteer species 2:1. Aspen and red maple were present on more than one-half of the plantations.

The nature of the climax succession on the three plantations is still unclear. Plantation 8 is in the beech forest type, and Plantations 3 and 7 are in the oak-hickory forest type. Aharrah and Hartman (1) speculated that coal spoils of western Pennsylvania will eventually be revegetated with oak-hickory forests because that is the climax vegetation of the area. In northern West Virginia, most iron ore spoils 85 to 119 years old were dominated by various oak species (16). In southern Illinois, however, volunteer oak seedlings found on various stripmine plantings at 18 years were absent at 30 years (2).

Other topics for additional study include determining the rate of growth of volunteer species and the response of both planted and volunteer trees to fertilization and crop tree thinning. A study of soil development on these plantations has been completed and will be published at a later date.

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APPENDIX

APPENDIX TABLE I.—Probability Levels of F-Tests of Plantation Location and Planted Species' Effects on Volunteer Trees. Data Were Analyzed Two Ways: First, Without Covariates of Number and Basal Area of Planted Trees Present on Subplots; and Second, with These Covariates Included in the Analysis.

		Total Volunteers			Black Cherry		Black Locust		White Ash	
Variables	d.f.†	No. of Species	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area
		probability levels								
Without Covariates:										
Plantations	2	<.001*	.010*	.119	<.001*	.004*	.370	.995	.078	.039*
Planted species	3	.115	.133	.957	<.001*	.018*	.002*	.128	.060	.483
Species x plantation	6	.001*	.013*	.501	.013*	.176	.412	.359	.062	.871
With Covariates:										
Plantations	2	<.001*	.003*	.174	<.001*	.041*	.461	.136	.343	.184
Planted species	3	.073	.329	.829	<.001*	013*	.002*	.021*	.128	.972
Species x plantation	6	.016*	.031*	.368	.160	.174	.254	.205	.112	.800

	Hawthorn Species		Red Maple		Elm Species		Dogwood		Sugar Maple	
Variables	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area
	probability levels									
Without Covariates:										
Plantations	<.001*	.044*	<.001*	<.001*	.396	.687	<.001*	.032*	.119	.386
Planted species	.291	.223	.007*	.315	.055	.482	.970	.617	.172	.672
Species x plantation	.241	.223	.001*	.225	.105	.654	.999	.881	.035*	.338
With Covariates:										
Plantations	<.001*	.076	<.001*	<.001*	.744	.637	<.001*	.018*	.051	.216
Planted species	.631	.614	.007*	.190	.051	.866	.743	.626	.528	.738
Species x plantation	.135	.183	.002*	.123	.489	.533	.992	.919	.054	.382

*Indicates probability levels of .05 (5%) or smaller.
†Degrees of freedom.

APPENDIX TABLE II.—Number of Each of 12 Additional Volunteer Species (Grouped as "Other" in Tables 3 and 4) on Plantations 3, 7, and 8.

Volunteer Tree Species	Plantation 3	Plantation 7	Plantation 8
		no./acre	
Apple species	0	0	17
Red oak	0	13	6
Willow species	0	0	14
Sweet cherry	0	13	0
Sycamore	6	0	2
Mulberry species	0	0	3
Green ash	0	6	0
Silver maple	0	0	1
Aspen	0	1	0
Sassafras	0	1	0
Basswood	0	1	0
Hophornbeam	0	1	0

APPENDIX TABLE III.—Common and Scientific Names of Trees Used in This Bulletin.

Common Name	Scientific Name
Apple	*Malus* species
Ash Green	*Fraxinus pennsylvanica*
Ash White	*Fraxinus americana*
Aspen	*Populus tremuloides*
Basswood	*Tilia americana*
Beech	*Fagus grandifolia*
Boxelder	*Acer negundo*
Cherry Black	*Prunus serotina*
Cherry Fire	*Prunus pennsylvanica*
Cherry Sweet	*Prunus avium*
Cottonwood	*Populus deltoides*
Dogwood	*Cornus florida*
Elm	*Ulmus* species
Hawthorn	*Crataegus* species
Hickory	*Carya* species
Hophornbeam	*Ostrya virginiana*
Locust Black	*Robinia pseudo-acacia*
Maple Red	*Acer rubrum*
Maple Silver	*Acer saccharinum*
Maple Sugar	*Acer saccharum*
Mulberry	*Morus* species
Oak Red	*Quercus rubra*
Oak Shingle	*Quercus imbricaria*
Oak White	*Quercus alba*
Persimmon	*Diospyros virginiana*
Pine Red	*Pinus resinosa*
Pine, White	*Pinus strobus*
Poplar Yellow	*Liriodendron tulipifera*
Redcedar	*Juniperus virginiana*
Sassafras	*Sassafras albidum*
Sycamore	*Platanus occidentalis*
Willow Black	*Salix nigra*
Willow	*Salix* species

The Ohio State University
Ohio Agricultural Research and Development Center